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External cervical resorption: A three-dimensional classification

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Abstract

This paper describes a novel 3-dimensional classification for external cervical resorption (ECR). The European Society of Endodontology and American Association of Endodontists & American Academy of Oral & Maxillofacial Radiology position statements advise that CBCT should be considered for the assessment and/or management of root resorption if it appears to be clinically amenable to treatment following clinical and conventional radiographic examination. The new classification takes into account the ECR lesion height (1: At CEJ level or coronal to the bone crest (supracrestal), 2: Extends into the coronal-third of the root and apical to the bone crest (subcrestal), 3: Extends into the mid-third of the root, 4: Extends into the apical-third of the root), circumferential spread (A: $\leq 90^\circ$ B: $\leq 180^\circ$ C: $\leq 270^\circ$ D: $>270^\circ$) and proximity to the root canal (d: Lesion confined to dentine, p: Probable pulpal involvement), thus classifying ECR in 3-dimensions. At present there is no classification to accurately describe ECR. A novel and clinically relevant 3 dimensional classification should allow effective and accurate communication of ECR lesions between colleagues. It will also allow the effect of the nature of ECR on the outcome of treatment to be assessed objectively.

Introduction

External cervical resorption (ECR) is initiated on the external aspect of the root, usually apical to the epithelial attachment. It is often aggressive in nature, resulting in significant loss of tooth structure (Heithersay 2004).

Although the aetiology of ECR remains unclear, it is understood to result from a deficiency of, or damage to the protective cementum immediately below the periodontal attachment (Gold & Hasselgren 1992, Neuvald & Consolaro 1992). The resorptive process is driven by odontoclasts, which initially penetrate the tooth through one or more small entry points and spread via numerous

channels (Schwartz *et al.* 2010). ECR may spread circumferentially and/or in a coronal-apical direction within the root. The root canal is surrounded by a protective layer, referred to as the pericanalar resorption-resistant sheet (PRRS) (Mavridou *et al.* 2016a). The PRSS is resistant to the resorptive process and consists primarily of predentine and dentine (Wedenberg & Lindskog 1987). Reparative (bone-like) tissue may also be deposited and nano-CT has shown this 'sheet' can be up to 490µm thick (Mavridou *et al.* 2016a). In advanced cases ECR may perforate into the root canal.

Clinically, ECR may present as a cervical cavitation, irregularity in the gingival contour and/or pinkish discolouration of the overlying enamel. However, in many cases there are no obvious clinical signs and detection is by an incidental radiographic finding (Patel *et al.* 2016). ECR may be misdiagnosed as caries, however, the lesion is distinguishable by its clinical appearance, hard cavity base and periodontal probing often results in profuse bleeding (Trope 2005, Patel *et al.* 2009a). The affected teeth are commonly asymptomatic until a late stage due to the presence of the pericanalar resorption-resistant sheet (Wedenberg & Lindskog 1987, Mavridou *et al.* 2016a). In advanced cases, the patient may present with pulpal and/or periapical symptoms (Patel *et al.* 2009a).

The radiographic appearance of ECR is variable and influenced by the size and nature of the lesion. It often appears as an irregular, asymmetrical radiolucency through which the root canal outline is traceable. Deposition of calcific tissue can result in a more radiopaque mottled appearance and this may represent a reparative stage in the development of the lesion (Iqbal 2007, Mavridou *et al.* 2016a).

Treatment aims to inactivate the resorptive process by removing the resorptive tissue and blood supply to the existing odontoclasts. The resorptive defect must be completely debrided and sealed to prevent revascularisation and further clastic action (Heithersay 2004). Therefore, effective management is dependent on good visualisation and accessibility to the lesion (Patel *et al.* 2009b,

Schwartz *et al.* 2010,). Early diagnosis and appropriate management has shown to improve the likelihood of tooth retention (Heithersay 1999a).

Report

Radiographic assessment of external cervical resorption

Periapical radiographs are essential to diagnose ECR. However, it is well established that they reveal limited information of the dentoalveolar anatomy because of their 2-dimensional nature, geometric distortion and anatomic noise (Bender & Seltzer 1961, Patel *et al.* 2015). Overlying ‘noise’ has shown to cause difficulty in detecting simulated external resorptive defects on conventional radiographs (Kamburoğlu *et al.* 2011, Bernardes *et al.* 2012). Anatomy can be visualised clearly in the mesio-distal plane but the third dimension (bucco-lingual plane) is compressed and cannot be assessed objectively. Therefore, ECR may only be assessed accurately on periapical radiographs when it is limited to the proximal aspects of the root. The limitations of radiographs have been reported to contribute to misdiagnosis, inadequate assessment and management of ECR (Patel *et al.* 2009b, Schwartz *et al.* 2010, Gunst *et al.* 2013).

Cone-beam computed tomography (CBCT) has become an increasingly important imaging device in diagnosis and treatment planning of complex endodontic problems (Brady *et al.* 2014, Ee *et al.* 2014, Hashem *et al.* 2015, Rodríguez *et al.* 2017). This is reflected in the recently published CBCT position statement by the European Society of Endodontology (2014), and the joint statement by the American Association of Endodontists & American Academy of Oral & Maxillofacial Radiology (AAE and AAOMR 2015). CBCT enables ECR to be viewed in any plane without superimposition of overlying structures and geometric distortion. Multiple images can be scrolled through easily producing a real-time dynamic image (Patel *et al.* 2015). This allows a detailed appreciation of ECR and its geometrical relationships. It is possible to visualise the fine resorptive projections extending from the

main lesion and the presence of more radiopaque ectopic calcified material (Patel *et al.* 2016, Mavridou *et al.* 2016b). This is important because these channels can communicate apically with the PDL and contain resorptive tissue and vasculature to propagate ECR. Failure to identify and remove the ectopic calcified tissue can also result in continued resorption beneath the fibro-osseous base, thus having a negative impact on the outcome of treatment (Estevez *et al.* 2010). Using CBCT, information regarding the true ECR size, location, circumferential spread, proximity to the root canal and accessibility can be gained. This information is crucial to determine if ECR is amenable to treatment and to formulate an appropriate treatment plan (Patel *et al.* 2016).

Several case reports have demonstrated that periapical radiographs often do not reflect the true nature of ECR compared to CBCT (Schwartz *et al.* 2010, Estevez *et al.* 2010). Further studies have confirmed that CBCT is more accurate than periapical radiographs in assessing external resorption (Durack *et al.* 2011, Bernardes *et al.* 2012, Ren *et al.* 2012, Vaz de Souza *et al.* 2017). Kamburoğlu *et al.* (2011) assessed observer ability to differentiate between simulated internal and ECR defects using an *ex vivo* model. CBCT images performed significantly better than periapical radiographs in conjunction with three parallax views in all aspects. These findings were corroborated by a clinical study, which showed the use of CBCT led to a more appropriate treatment plan chosen to manage these lesions (Patel *et al.* 2009).

Heithersay (1999b) devised a classification to categorise ECR according to its size and proximity to the root canal. The classification is based on conventional radiographs and categorises ECR according to the penetration of the lesion into coronal and root dentine: Class I, a small cervical lesion with shallow penetration into dentine; Class II, a well-defined lesion close to the coronal pulp but with little or no extension into radicular dentine; Class III, deeper invasion of the lesion into the coronal third of the root; Class IV, a lesion extending beyond the coronal third of the root (Heithersay 1999b). This classification is only relevant if ECR is limited to the proximal aspect of a tooth and can be

clearly assessed in 2-dimensions. It becomes difficult to use when the lesion is on the buccal/ lingual aspect of the root. It also fails to describe the circumferential or pulpal involvement of the lesion (Figure 1). Therefore, most ECR lesions become impossible to properly describe in 3 dimensions using the current classification. Now that cone beam-CT has become an important and frequently used part of ECR diagnosis and treatment planning, a 3-dimensional classification has become increasingly necessary.

Vaz de Souza *et al.* (2016) compared the diagnostic efficacy of periapical radiographs with CBCT to detect and classify simulated ECR lesions using an *ex vivo* model. Simulated lesions were prepared to different sizes to represent each of the Heithersay categories. This study confirmed that CBCT had a significantly higher sensitivity, specificity and overall accuracy than periapical radiographs when assessing the size and location of ECR. Examiners found it difficult to identify the correct Heithersay classification in 48.5% and 70% of cases using PR and CBCT, respectively. In addition, there was a significantly lower intra- and inter-examiner agreement with periapical radiographs when compared to CBCT (Vaz de Souza *et al.* 2016). These results question the validity and reliability of the Heithersay classification and may be explained by the limitations of using a 2-dimensional PR to classify complex 3-dimensional ECR lesions.

A recent clinical study assessed 115 ECR lesions using periapical radiographs and CBCT (Patel *et al.* 2016). Receiver operating curve (ROC) analysis showed periapical radiographs had significant limitations in the detection of ECR and assessment of lesion size (0.75), circumferential spread (0.60) and location compared to CBCT (1.0). This resulted directly in a significant difference in the treatment plan formed by the 6 examiners. Parallax radiographs were shown to be of no additional benefit compared with a single radiograph. The study concluded that a CBCT scan should be considered before the management of a potentially restorable ECR lesion. The study used the Heithersay classification to define the size of the lesion but needed to introduce further categories,

such as lesion circumference and location, in order to effectively describe the lesion. This highlights the limitations of the Heithersay classification to characterise ECR lesions. In addition, if the ECR lesion can not be accurately classified it may have a negative impact when the outcome of treatment is assessed.

The use of CBCT to assess and manage root resorption has been recommended in the European Society of Endodontology position statement (2014) and AAE/AAOMR (2015) position statements. Taking into account the aforementioned studies which confirm the increased accuracy of CBCT compared to Periapical radiographs in determining the nature and location of ECR, it would be desirable to have a clinically relevant 3-dimensional classification for ECR.

A new descriptive classification for ECR

This new clinical classification takes into account the lesion height, circumferential spread and proximity to the root canal, thus classifying ECR in 3-dimensions (Table 1).

Height

The height (coronal-apical extent) of the lesion is graded according to its maximum vertical extension within the root surface and the level of the bone crest. The level of the bone crest relative to the lesion is relevant to treatment planning. The root is divided into the coronal, middle and apical third, using the cemento-enamel junction and apex as fixed reference points. The height of the lesion can be best assessed using periapical radiographs, and the coronal and sagittal CBCT views (Figure 2).

1: At cemento-enamel junction level or coronal to the bone crest (supracrestal)

2: Extends into coronal-third of the root and apical to the bone crest (subcrestal)

3: Extends into mid-third of the root

4: Extends into apical-third of the root

Circumferential Spread

The circumference of the lesion is graded according to its maximum spread within the root. This can be best assessed using axial CBCT views (Figure 2).

A: $\leq 90^\circ$

B: $> 90^\circ - \leq 180^\circ$

C: $> 180^\circ - \leq 270^\circ$

D: $> 270^\circ$

Proximity to the root canal

The proximity of the lesion to the root canal can be best assessed using axial CBCT views (Figure 2).

d: Lesion confined to dentine

p: Probable pulpal involvement

The maximum height, circumferential spread and depth of the lesion is noted after assessing the periapical radiograph and CBCT scan, thus giving a three-dimensional grading of the lesion (Figure 3).

Discussion

Numerous studies have shown ECR to have an unusual and complex pattern of invasion, which can make assessment challenging (Patel *et al.* 2016, Vaz de Souza *et al.* 2016). *In vivo* CBCT and *ex vivo* micro-CT or nano-CT have revealed the complex pattern of ECR invasion, portal of entry, small channels and their interconnections with the PDL (Schwartz *et al.* 2010, Gunst *et al.* 2013, Mavridou *et al.* 2016a). A three-dimensional ECR classification is important and relevant because these studies have shown that ECR often spreads differently in all three dimensions.

Ex vivo and clinical studies have confirmed that periapical radiographs often underestimate the size of ECR and cannot depict the true nature of these lesions. Conversely, CBCT has shown to be a reliable diagnostic tool in assessing ECR. Observers are reported to be consistently better at detecting lesions and identifying their size, location and circumferential spread (Kamburoğlu *et al.* 2011, Vaz de Souza *et al.* 2016, Patel *et al.* 2016). CBCT has also been shown to be accurate at depicting ECR lesions when assessed against matching histological sections (Mavridou *et al.* 2016a). This gives a three dimensional insight into the lesion and ability to determine the most suitable treatment plan (Patel *et al.* 2009c, Gunst *et al.* 2013). Numerous case (series) reports have also demonstrated that radiographs often do not reflect the true nature of these resorptive lesions compared to CBCT (Patel *et al.* 2009b, Schwartz *et al.* 2010, Estevez *et al.* 2010). These factors can result in misdiagnosis and ineffective or inappropriate management. The European Society of Endodontology (2014) position statement and AAE & AAOMR (2015) joint position statement advise that CBCT may be considered for the assessment and/or management of root resorption if it appears to be clinically amenable to treatment following clinical and conventional radiographic examination. The increasing use of CBCT means a three-dimensional ECR classification is desirable to accurately describe these often complex (3 dimensional) lesions.

The outcome of treatment is known to depend on the characteristics of the pre-existing ECR lesion (Heithersay 1999a). The height, depth and circumferential spread of ECR lesions is likely to impact tooth survival and treatment success. This new classification can be used to report future outcome studies and can hopefully gain an insight into prognostic factors, which may facilitate the management of these lesions and improve tooth survival.

It is imperative that the principles of ALARA (As Low As Reasonably Achievable) are adhered to and CBCT scans are fully justified over conventional techniques prior to being carried out (Pauwels *et al.* 2012). The effective dose for a periapical radiograph is between 1-5 μ Sv and a small field of view (FOV) CBCT scan ranges between 11-29 μ Sv (Loubele *et al.* 2009). There can be significant benefits of a CBCT scan for detecting and managing ECR (Patel *et al.* 2016). However, there is little justification for a CBCT scan if ECR already appears unrestorable on a periapical radiograph because this has shown to underestimate lesion size. Reducing the arc of rotation from 360° to 180° has shown to have no effect on the diagnostic yield when assessing simulated external inflammatory or periapical lesions (Durack *et al.* 2011, Jones *et al.* 2015, Al-Nuaimi *et al.* 2015). Alteration of the exposure parameters may further reduce the patient dose whilst still enabling accurate diagnosis and assessment of ECR lesions. This should be investigated further (Al-Nuaimi *et al.* 2015).

Conclusion

This paper proposes a new 3-dimensional classification of ECR. This will allow:

- effective and accurate communication of ECR lesions between colleagues
- treatment outcome and prognostic factors to be assessed in relation to the 3-dimensional nature of ECR

Conflict of Interest statement

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

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Figure Legends

Figure 1 Limitations of Periapical radiographs to assess ECR lesions and problems with the ‘Heithersay classification’ system (a) PR of tooth 11. It is not possible to classify this lesion (red arrow) using the Heithersay classification because it’s depth cannot be assessed. It is also not clear if the lesion is located on the buccal or palatal surface (b-c) CBCT images reveal that the lesion is larger than projected on the PR. The lesion extends close to the pulp and has spread circumferentially around the root canal (yellow arrow) (d) PR of tooth 16. The ECR lesion is difficult to fully visualise, locate and classify (e-f) CBCT images show the lesion is extensive and spreads into the mesio-buccal

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root, resulting in the tooth being unrestorable (g) PR of tooth 25 and 26. It is difficult to visualise the ECR lesion tooth 25 and there does not appear to be a lesion on tooth 26 (h-i) CBCT images show ECR lesions on both teeth. Small ECR channels (yellow arrow) can be seen extending close to and circumferentially around the pulp (j) PR of tooth 27. The ECR appears small (Heithersay classification 1 or 2) (k-l) CBCT images show the lesion is more extensive and not amenable to treatment. The sagittal slice shows the ECR has spread up the distobuccal root and the axial slice shows the circumferential spread around the root canals (yellow arrow). These cases highlight that Periapical radiographs do not accurately represent ECR lesions compared to CBCT images. The Heithersay classification cannot accurately describe the differences seen between these lesions.

Figure 2 The proposed 3D classification describes ECR lesion height, circumferential spread and proximity to the root canal. The height of the ECR lesion on tooth 21 is measured using (a) PR (b) sagittal CBCT slice (c) coronal CBCT slice. The horizontal white lines split the root into the coronal, middle and apical third, using the cemento-enamel junction and apex as fixed reference points. The level of the bone crest (yellow dotted line) can be best seen on the sagittal CBCT slice. The height of the ECR lesion can be classified as; **1**: At cemento-enamel junction level or coronal to the bone crest (supracrestal), **2**: Extends into coronal-third of the root and apical to the bone crest (subcrestal), **3**: Extends into mid-third of the root, **4**: Extends into apical-third of the root. This ECR lesions height can be graded as **1**. The circumference of the ECR lesion and its proximity to the pulp can be assessed using axial CBCT images (d) Axial slice of tooth 21 demonstrating a size **Ad** ($\leq 90^\circ$ lesion, confined within dentine) (e) Tooth 24 showing a size **Dp** ($> 270^\circ$ lesion, with probable pulpal involvement).

Figure 3 Example of new 3D classification; the ECR lesion is shown by the red arrow and level of the bone crest is marked by the yellow dotted line. (a) PR of tooth 31 (b-c) CBCT images showing the maximum diameters of the lesion. This ECR lesion can be graded size **1Ad** (d) PR of tooth 35 (e-f) CBCT images. This ECR lesion can be graded size **2Bp** (g) Periapical radiograph of tooth 35 (h-i) CBCT images. This ECR lesion can be graded size **3Dp**.

Table 1 3-dimensional classification of ECR.

Height	Circumferential spread	Proximity to the root canal
1: At cemento-enamel junction level or coronal to the bone crest (supracrestal)	A: $\leq 90^\circ$	d: Lesion confined to dentine
2: Extends into coronal-third of the root and apical to the bone crest (subcrestal)	B: $> 90^\circ - \leq 180^\circ$	p: Probable pulpal involvement
3: Extends into mid-third of the root	C: $> 180^\circ - \leq 270^\circ$	
4: Extends into apical-third of the root	D: $> 270^\circ$	





